

# Management of Small Docks and Piers

## Environmental Impacts and Issues

### Forward—

This and the other related sections of the following workbook—along with the complementary PowerPoint presentations—were funded through the National Oceanic and Atmospheric Administration's (NOAA) National Centers for Coastal Ocean Science (NCCOS) and the Office of Ocean and Coastal Resource Management (OCRM). Steve Bliven of Bliven & Sternack prepared the text and slides under contract to those offices. All those concerned would like to thank the reviewers who offered valuable comments on drafts of this document.

### Introduction—

Private docks have been implicated in a number of environmental impacts. Some of these have received scientific investigation and some remain anecdotal. In an attempt to clarify what is known about environmental impacts from docks, NOAA's National Centers for Coastal Ocean Science convened a workshop in January of 2003. This session brought together scientists and a group of coastal managers from across the country to discuss the environmental impacts of small docks. The results of that workshop may be found in Kelty and Bliven (2003).

The workshop identified four general impacts:

- Impacts to vegetation
- Impacts from contaminants related to docks
- Impacts from associated boating use
- Impacts to sediments and substrate

Impacts to wildlife habitat were discussed as part of the topics above, as this is a significant cross-cutting issue.

## Impacts to Vegetation from Small Docks—

Marsh plants and submerged aquatic vegetation (SAV) are ecologically critical as a source of food and nursery habitat for fish, shellfish, amphibians, reptiles, birds and mammals that live in coastal waters or the adjacent marsh and uplands (Weigert *et al.*, 1981; Teal, 1962, 1969; Weinstein, 1996). Vegetated areas also stabilize shoreline and bottom sediments against erosion (Kearney *et al.*, 1983; Teal, 1986) and take up contaminants and excess nutrients from the water and sediments (Vernberg, 1996).

Impacts to plant health and productivity from docks generally occur in one of the following ways:

- Short-term construction impacts,
- Chronic impacts from shading,
- Chronic impacts from storage of floats and boats and associated foot traffic, and
- Impacts from boat use (covered later in this module as a separate topic).

### *Short-Term Construction Impacts—*

Activities during construction can destroy plants either above the tide line (*e.g.*, marsh grasses such as *Spartina* or *Distichlis*) or below (*e.g.*, sea grasses such as *Zostera* or *Halodule*) by pulling them from the substrate or destroying their root systems. The peat beds underlying salt marshes can be compacted through the improper use of heavy equipment leading to ponding of saline waters and a resultant loss or changing of marsh vegetation. Although these impacts are seemingly evident, limited research appears to have been done on the long-term effect of these activities.

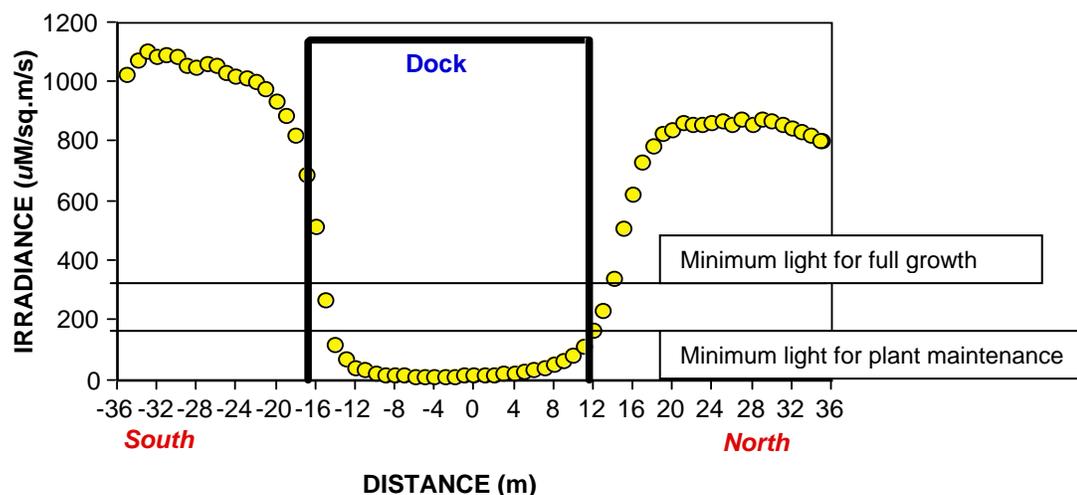
Setting pilings in sea grass beds may have immediate impacts as well as causing long-term changes. The act of installing pilings destroys any vegetation within the footprint of the pilings. The use of “jetting” with high-pressure hoses typically disturbs adjacent vegetation and sediments—depopulating grasses existing there prior to construction. Once areas are depopulated, the presence of pilings may lessen chances for regrowth. Beal, Schmit, and Williams (1999) suggest that changes in seagrass communities in the vicinity of pilings may be caused by the modification of currents, sediment deposition, attraction of bioturbators, and leaching from chemically treated wood.

Shafer and Robinson (2001) tracked the regrowth of the seagrass *Halodule wrightii* beneath docks in St. Andrew Bay, FL. They noted bare areas from 35–78 inches in diameter around pilings, “even though the age of these docks varied widely” suggesting that regrowth is affected by the presence of pilings. Use of high pressure jetting produced a six- to seven-foot diameter hole around each piling, which was then backfilled to hold the piling in place. The resultant “halo” might remain for 10 years without seagrass regrowth. The authors found that where piles were installed using low-pressure jetting techniques there was, “little or no sand deposition around the pilings and the remaining seagrasses around the pilings looked healthy and had good growth around the piling.”

Dock construction also impacts marsh grass. Sanger and Holland (2002) noted a barren path through the marsh along each side of a newly constructed dock in North Carolina where vegetation had been almost totally destroyed. However, construction did not appreciably alter the original marsh elevations. Resurveying the site 15 months later, the researchers found that *Spartina alterniflora* had recolonized the area and substantial recovery had occurred.

### Chronic Impacts from Shading—

Both marsh grasses and sea grasses have adapted to living in extended periods of sunlight. Therefore, shading can have significant impacts on the health and productivity of these plants. Figure 1 illustrates some of the potential impacts from dock shading. Two thresholds are shown; the minimum amount of light necessary for the plant to reach full growth, and the minimum amount of light for the plant to sustain itself. Below the first threshold, plants are stunted in growth or grow tall and spindly in an attempt to reach sunlight. Below the second threshold, plants die.



**Figure 1.** Light Profile under a dock (From Nightengale and Simenstad 2001. Ron Thom, pers. comm.). The graph illustrates how the shading of an east-west oriented dock affects light levels and vegetation growth below a dock in Washington state. The two horizontal lines indicate the light levels necessary for full, unaffected growth of plants (Minimum light needed for full growth) and the amount of light for plants to live (Minimum light for plant maintenance). Note that much of the area beneath the illustrated dock is below the threshold for plant life. Note also that the shading is somewhat offset to the north due to the declination of the sun.

### Amount of Light Required by Vegetation—

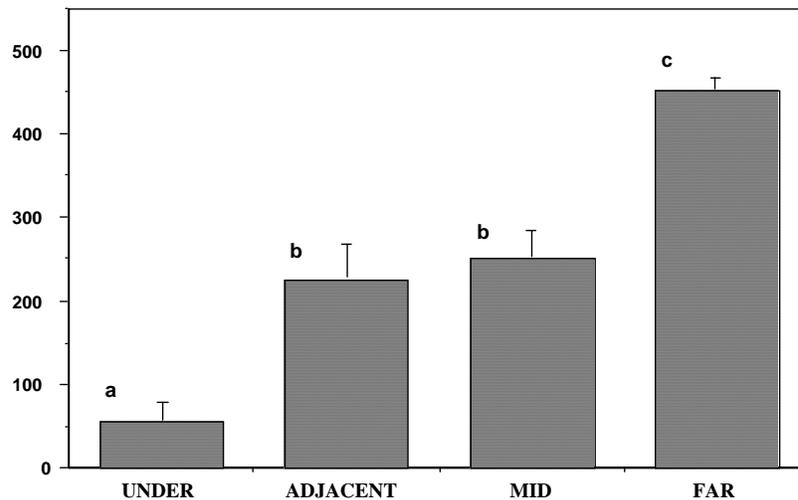
Susceptibility to shading varies by species, even those occupying similar habitats. For example, in marsh grasses, densities of *Spartina patens* (Salt Meadow Grass or Salt Hay Grass) and *Distichlis spicata* (Spike Grass or Salt Grass) are more sensitive than *Spartina alterniflora* (Smooth Cordgrass or Saltwater Cordgrass) (Kearney *et al.* 1983).

Light levels necessary for plants to sustain themselves generally range between 12–25 percent of ambient light, depending on the species. Specifically for seagrasses, a National Marine Fisheries Service (NMFS) Technical Memorandum reports that “the light requirements of temperate and tropical seagrasses are very similar” requiring “at least 15 to 25% of the incident light just for maintenance” (Kenworthy and Haurert, 1991). Light requirements are presumably higher to allow full growth but there has been limited research that provides specific percentages.

NMFS' summary report is supported by studies on individual seagrass species. For example, Shaefer and Robinson (2001) report that light levels of 13–14 percent of mean daily surface irradiance (SI) are necessary for survival of the seagrass *Halodule wrightii*. Shaefer (1999) found that seagrass densities were 40–47 percent less in areas shaded at levels of 16–19 percent SI. Burdick and Short (1999) observed similar trends in the eelgrass, *Zostera marina*, which required light levels of at least 15 percent of surface irradiance for survival and approximately 50–60 percent for healthy beds.

### Direct Impacts of Shading—

As we have already demonstrated, marsh and submerged aquatic vegetation need adequate light levels to survive and flourish. Therefore shading from docks can have significant implications for this vegetation. Recent studies have shown that shoot density, biomass, and overall plant growth may be reduced by dock shading (Sanger and Holland, 2002; McGuire, 1990; Burdick and Short, 1999). In some instances, researchers found an increase in the height of marsh grasses found under docks, possibly due to etiolation. (Etiolation is a condition in which plants growing in reduced light levels elongate much more rapidly than normal as a means of reaching light. It is characterized by long weak stems and small leaves.)



**Figure 2.** Eelgrass density was significantly lower under and near docks than at sites removed from the dock by various distances (Burdick and Short, 1999).

Impacts due to shading also appear in fresh waters. Garrison *et al.* (2005) investigated shading impacts on submerged vegetation and relationships to fish and invertebrate habitats. They found significant shading under docks “with a corresponding reduction in aquatic plant abundance” in Wisconsin lakes. By placing unbaited minnow traps below piers and within nearby, control vegetated zones, the researchers also found decreased numbers of macroinvertebrates and vertebrates as well as changes in species composition. Wilson (2002), working in fresh-tidal waters in Connecticut, found that not only did shading have impacts on existing submerged aquatic vegetation but it also adversely affected its ability to regenerate after being mechanically disturbed. (Wilson manually clipped the submerged vegetation in his research but suggests that similar effects would be found from disturbance by boat propellers.)

### Geographic Area Affected by Shading—

It is clear that shading from docks can have an adverse impact on the underlying vegetation but one of the questions coastal managers grapple with most is how much total marsh grass or seagrass will be affected by docks, and will the addition of more docks have a significant impact on the total amount of vegetation present. Sanger and Holland (2002) compared the area of marsh affected by docks to the total area within specific creek systems and also estimated the amount of marsh affected by docks throughout coastal South Carolina. Based on the number of docks present in 1999, they estimated that docks reduced *S. alterniflora* densities by 0.03–0.72 percent within their study sites. When they projected to a total possible build-out of similarly sized docks in the creek systems, Sanger and Holland calculated that docks would cause a 0.18–5.45 percent decrease in marsh grass. Finally, Sanger and Holland applied this approach to the projected build-out of docks for all eight coastal counties by the year 2010. They estimated that a reduction in marsh density of between 0.03–1.98 percent could be attributed to dock impacts.

Smith and Mezich (1999, in Shafer 2001) note that up to 50 acres of seagrass beds had been negatively impacted in the early 1990s by single-family docks in the Palm Beach County, Florida. Studies in Georgia (Alexander and Robinson, 2004) suggested a maximum estimate of 4–6 percent of the marsh around Wilmington Island could be shaded if full build-out should occur under the provisions of current state laws.

It should be noted that the significance of these shading impacts to the coastal ecosystem as a whole varies by region and the amount of salt marsh or seagrasses present. In areas where coastal vegetation is already severely reduced or otherwise impacted (e.g., New England and Florida) affected areas as a percentage of the entire marsh system could be higher than those reported for South Carolina and Georgia.

### Indirect Impacts of Shading—

Changes in vegetation density and hardness may lead to increasing sediment erosion and resuspension, and increased undercutting of the marsh shoreline near the dock because robust healthy marsh and seagrass vegetation is no longer present to hold the sediments in place (Burdick and Short 1999).

Burdick and Short (1999) also found that shading of eelgrass beds can lead to fragmentation, thereby disrupting wildlife habitat. The work of Garrison *et al.* (2005) mentioned previously showed that the loss of vegetation due to shading by docks reduced fish and large invertebrate abundance and altered species composition in Wisconsin lakes.

A subsequent effect of the shading by docks in Connecticut was reported to be accelerated soil erosion beneath structures passing over *S. alterniflora* at the edge of the marsh (Kearny *et al.* 1983).

### Factors that Affect Shading—

Kearny *et al.* (1983) studied impacts to marsh grasses from walkways/docks from “all the structures” within Connecticut’s major salt marsh regions, collecting data on vegetation density and height beneath and adjacent to the structures, and the physical dimensions of the docks (width, height, plank width, and spacing between planking—they did not include orientation). They found that dock height was the only statistically significant variable; docks less than 12–16 inches above the marsh shaded out all vegetation in every study site. Any impacts from dock

width, plank width, and plank spacing were not statistically significant. However, it should be noted that a National Marine Fisheries Service study that assessed dock impacts on marsh grass vegetation in Connecticut, Rhode Island, and Massachusetts cast some doubt on the methodology and statistical analyses of Kearney *et al* (1983) (Colligan and Collins, 1995).

In a field study conducted in Waquoit Bay, Falmouth/Mashpee and Nantucket Harbor (all in Massachusetts), Burdick and Short (1999) found that dock height was not the only factor influencing shading impacts on eelgrass beds but that the orientation of the dock and dock width also played significant roles. According to their data, North-South orientated docks had less impact than East-West orientated ones.

While orientation may be an important factor in northern latitudes, it may not play a significant role in lower latitudes. Sanger and Holland (2002) assessed impacts on *S. alterniflora* from 32 docks in the Charleston, SC area. The structures represented a range of lengths, orientations, and ages. They found no significant difference in reduction in *S. alterniflora* density due to shading between North-South oriented docks and those with an East-West orientation.

The National Marine Fisheries Service suggests that spacing between decking planks on the order of an inch or two has little effect on shading impacts, particularly in northern latitudes (Michael Ludwig, NMFS, Personal Communication, 2003). There appears, however, to have been little systematic research on this topic.

In summary, it appears that dock height and width are significant factors that contribute to shading impacts on vegetation. However, but it is still unclear whether orientation and spacing between decking boards have measurable impacts. There appear to be differences in these impacts between northern and southern latitudes.

#### Models to Predict Shading—

McGuire (1990) measured the effects of shading by open pile structures on *S. alterniflora* density in a fringe marsh in the York River Estuary (VA). She subsequently developed a computer program to calculate the total number of hours of shading produced by each structure based on height, width and orientation of the structure and compared the computer projections with the results of her field studies. The computer program developed as part of this project appears to hold promise as a predictive tool. Unfortunately, no electronic copies of the program remain (the text of the program is available) and it is written in Pascal. To be effective the program would have to be rewritten in a contemporary, and more user-friendly, format.

Burdick and Short (1998) modeled the impact of shading on eelgrass. They presented their results in an informational CD entitled "Dock Design with the Environment in Mind: Minimizing dock impacts to eelgrass beds." The CD contains illustrative estimates of impacts to *Zostera* from docks of specific height, width, and orientation. They did not attempt to develop a process to assess the impacts from differently sized and oriented docks but feel that a computer model could be produced to predict impacts from any combination of design factors (personal communication, 2005).

#### Cumulative Impacts from Shading—

The issue of cumulative impacts to vegetation from shading or dock construction has not been heavily researched. Consequently is it not clear whether such impacts are additive or have some greater effect.

#### *Chronic Impacts from Storage of Floats and Boats—*

Floats, boats, or any other solid structure stored, either permanently or seasonally on the marsh face will significantly shade, and therefore destroy, any vegetation present.

#### *Ramifications of Impacts to Vegetation—*

Shading of vegetation, to the point where its health is impaired, can have several adverse impacts.

#### Lessening of input to the Aquatic Food Web—

Marsh and seagrass vegetation and the detritus they produce constitute a major portion of food available to the base of the aquatic food web. For example, these habitats are critical to the life cycle of shellfish and juvenile finfish that inhabit embayments and estuaries. Significant loss of vegetation may adversely affect populations of these species (Teal, 1986).

#### Modification of topography and lessening productivity of the marsh—

Compaction of marsh peat from construction or continually walking to and from a dock changes the marsh topography and may lead to long-term changes in marsh vegetation and drainage (Hruby, 1990). The distribution and species of marsh vegetation are strongly linked to elevation in relation to tidal flooding. Ponding of salt water on the marsh face will eventually lead to changes in vegetation to less productive species (Lefor, 1992).

#### *Fragmentation of habitat—*

Marshes are important for many species, including fish, birds, mammals and reptiles. Similarly many aquatic organisms, including game fish, shellfish, and the food they eat, depend on submerged aquatic vegetation. Docks, piers and associated walkways to docks fragment these valuable wetland habitats. The presence of docks or subsequent damage to the surrounding vegetation can deter wildlife from frequenting the area. Small docks also fragment eelgrass beds (Burdick and Short, 1999)—primarily through shading of the grasses. There are, unfortunately, limited research results available to quantify the impacts due to habitat fragmentation.

There is a body of empirical evidence showing that fragmentation of habitat causes changes in species diversity and composition (Wilson, 2002). These changes may be in small beds or an entire estuary. Rare or specialized species tend to be the first to disappear from impacted environments (Wilson, 2002).

## Impacts from Contaminants Related to Docks—

The most common contaminant-related concern associated with small docks is leaching of wood preservatives. Wood continuously exposed to water can decay rapidly. Pilings are also subject to wood-boring and fouling organisms that speed their break-down. To protect the wood and ensure docks will have a reasonable lifespan, the wood is typically treated with preservative chemicals that, in turn, can leach into surrounding waters. Historically, the most commonly used materials were oil-based: creosote or pentachlorophenols. Presently, wood products pressure-treated with chromated copper arsenate (CCA) are the most common material used for dock construction.

### *Creosote and Pentachlorophenol—*

Oil based preservatives containing creosote (CRT) or pentachlorophenol (PCP), applied to the surface of wood materials, leach readily and have wide-spread environmental and human health impacts. Most states have banned their use for small docks and piers.

### *Chromated copper arsenate (CCA)—*

CCA-treated wood comes in a variety of “strengths” (the amount of preservative retained in the wood after treatment). The Southern Pine Council (2004) makes the following recommendations for specific uses:

<b>Concentrations of CCA Wood Treatments Recommended for Various Uses</b>	
<b>Retentions (lbs./cu.ft.)</b>	<b>Uses/Exposures</b>
0.10 – 0.25	Above ground
0.21 – 0.41	Soil & Freshwater use
0.31– 0.61	Permanent Wood Foundation
2.50	Saltwater use

**Table 1.** Concentrations of CCA wood treatments recommended for various uses.

As can be seen, protection of wood products, generally pilings, in marine waters requires a far heavier treatment than in most other environments.

Weis *et al.* (1991, 1992), in laboratory studies, found that leaching occurs in saline waters and that it can have toxic effects. The leaching rate decreases by about 50% daily once the wood is immersed in seawater. Approximately 99% of the leaching occurs within the first 90 days in the marine environment. (Cooper, 1990; Brooks, 1990; in Sanger and Holland, 2002).

The metals that leach from CCA-treated woods (Copper, Chromium, and Arsenic) adsorb more readily onto fine-grained sediments (silts and clays) than sand (Luoma and Davis, 1983). Field studies by Weis *et al.* (1992, 1998) found elevated concentrations of metals in fine sediments adjacent to (within 1 meter) bulkheads (solid walls of treated lumber, as opposed to dock pilings) constructed of CCA-treated material. The distance at which elevated levels could be

found varied according to the sediment types. At most test sites, the impacts were limited to one meter from the structure. In some other sites where fine-grained sediments were predominant, the elevated levels could be found out to approximately 10 meters (Weis *et al.*, 1998).

Elevated concentrations of metals from CCA-treated wood can be found in organisms living on treated pilings and in the areas near to the pilings (Wendt *et al.*, 1996; Weis and Weis, 1996). In sediments with higher contaminant levels, species richness was depressed (Weis and Weis, 1998).

Snails in the laboratory fed marine algae gathered from CCA-treated pilings became inactive in 3-4 weeks; they initially curled up inside their shells and then died (Weis *et al.*, 1991). A field study of oysters living on CCA-treated wooden bulkheads showed that they were smaller than control populations and had taken up measurable levels of copper (Weis *et al.* 1993). When copper concentrations are high enough, the oysters' digestive glands shrink, leading to death. Wendt *et al.*, (1996), however, evaluated uptake of metals by white shrimp, mud snails and two species of fish (mummichogs and red drum) and found no increase in mortality in individuals placed adjacent to 5–12 month old docks for 96 hours. As noted previously, 99% of all leaching occurs within the first three months; the 5–12-month age of the docks in Wendt *et al.*'s study is outside the period when significant leaching occurs.

Factors involved in impacts to biota appears to include sediment type (mentioned above), amount of CCA-treated material (piers vs. bulkheads), length of time the CCA-treated material has been immersed in marine waters (more than or less than 3 months), and the flushing rate of the water body. In an unpublished "gray literature" study prepared for the New Jersey Department of Environmental Protection, Weis and Weis (1998) looked at sediments and shellfish in the Navesink-Shrewsbury River system (NJ) in relation to distance from docks constructed with CCA-treated materials. They found that concentrations of metals in sediments adjacent to pilings at their test sites "were generally not significantly elevated ... it appears that leachates from pilings, in reasonably flushed areas have negligible ecological effects, while those from bulkheads, particularly new ones and ones in poorly flushed regions, have demonstrated, clear-cut, ecological effects." Sanger and Holland (2002) report that, "it is unlikely that the bioaccumulation of dock leachates by marine biota is having or is likely to have an impact on living resources in South Carolina estuaries and tidal creeks." Reasons given are that approximately 99% of the leaching takes place in the first three months after installation, that the size of the area around the dock that might be affected is small, and high rates of tidal flushing will dilute and flush any accumulations in the water column.

While Weis *et al.* (1991) noted mortality in snails fed algae grown on CCA-treated wood in laboratory tanks, there have been, thus far, no reports of the transfer of metals from the CCA treatment up the food chain to higher predators (P. Weiss in Kelty and Bliven, 2003).

As of 2004, pressure-treated lumber intended for residential and recreational (including docks in freshwater) is no longer treated with CCA. (CCA-treated materials are still used in marine waters.) Alternative treated wood intended for freshwater applications include: Alkaline Copper Quat (ACQ) and Copper Azole (CA, "Wolmanized"®). These are not recommended for marine use.

To summarize, issues to consider in management decisions relating to CCA-treated materials include:

- the area of exposed surface of CCA-treated materials (bulkheads have greater surface exposed to water than dock pilings so have a greater potential to leach contaminants into the environment),
- the age of the materials used (most leaching occurs within the first 90 days,
- the types of sediments in the area (fine-grained sediments with high organic content take up more contaminants than larger grained sediments), and
- the flow of water through the system.

Despite these research efforts however, a tidal flushing threshold for contaminant impacts has not been identified, and data do not exist to evaluate the importance of dilution in high flow areas with different benthic community composition.

*Impacts from Flotation Materials—*

Plastic, non-enclosed foam billets are occasionally used as flotation material for docks. Sometimes referred to by the tradename Styrofoam or “beadboard.” Open-cell foam absorbs water over time and reduces flotation support. More importantly to environmental effects, it breaks down easily into small beads that are virtually indestructible. Pieces of these billets may litter the shoreline or be ingested by wildlife. It may choke air-breathing species or take up considerable space in the digestive tract of species that ingest it, lessening their ability to take up nutrients. Use of this material as dock flotation has been banned in many jurisdictions (Burns, 1999).

*Impacts from Painting and Seasonal Upkeep—*

Painting, staining, scraping or other seasonal maintenance to docks can introduce contaminants into the water column. To avoid potential pollution caused by this type of dock maintenance activity, the Maine State Planning Office (1997) discourages painting and staining, suggesting that “all coatings pose a local environmental threat, damage flotation materials, and have only minimal effect on a structure’s longevity.”

*Impacts from Fuel Leakage—*

Fueling that takes place at small docks generally consists of pouring fuel from a portable tank into an outboard engine’s fuel tank—often with the engine attached to the stern of the boat directly over the water. This offers the opportunity for spillage or overflows. Poorly designed or maintained engines also may discharge fuel during operation. Petroleum products in marine waters can have significant impacts to be discussed further in the following section on boating impacts.

## Impacts of Small Docks on Sediments and Sedimentation—

During a permit review or planning exercise, coastal managers sometimes hear concerns that small, pile supported docks may cause changes to sediments topography and composition in the vicinity of the structure. This may be attributed to erosion, increased sedimentation, or resuspension and movement of specific particulate sizes or types. Generally, one of the following three mechanisms are suggested:

1. Changes in water movement due to pilings redirecting water flow or speeding movement around the pile resulting in scour,
2. Disruption of sediments during piling installation,
3. Suspension of sediments as floats or boats attached to docks touch or approach the bottom at low tides and lift sediments as they rise with the tide (“pumping”).

### *Altering currents—*

Structures placed in moving water have the capability to disrupt the water’s flow. Piles may cause increased flow rates immediately around their base leading to scour and erosion. They may also lead to a general slowing of flow over the area of the dock, resulting in settling out of sediments carried by the current. The resulting changes in sediments caused by scour or deposition may affect fish shellfish or habitat.

There appears to be very little in the way of research results available on the impacts on sedimentation from small pile supported structures. What research has been reported was done in open ocean settings, not in embayments, and most focused on the morphological changes to adjacent shorelines and bottom topography—no information was located on the nature of sediment type change, if any, over time in the vicinity of pile-supported piers.

What literature was located was done in the 1970s. Noble (1978) assessed the impacts of 20 piers—all situated within the Southern California Bight. These piers ranged from 625–2,500 feet in length and 15–300 feet in width—far larger than the small recreational facilities under consideration here. All of the piers studied had pile spacing greater than 4 times the diameter of the piles. Noble found that these piers “had a negligible effect” on sedimentation and erosion of adjacent shorelines. He notes that his results support prior findings of Johnson (1973) and Evert and DeWall (1975).

Miller *et al.*, (1983), researching the impacts of an 1,840-foot long, 20-foot wide pier near Duck, NC on the Atlantic coast found that the pier produced a permanent trough under the pier reaching a maximum depth of 9.9 feet. Scour around individual pilings was noted to be on the order of 3.3 feet in depth. The pilings in this case are 30 and 36 inches in diameter spaced 15 feet on center across the pier and 40 feet on center along its length.

In an engineering study related to Lagoon Pond on Martha’s Vineyard, MA, Poole (1987) suggests that, “At a wind angle of 90° to a 50-foot pier with 5 pilings on each side [diameter of pilings not noted—ed.] can [sic] produce eddy currents and flow friction 2 times the diameter of the pilings—minimally. This means...a 30 percent reduction in flow. The area or parallel shoreline affected by the flow reduction would be a factor of 2 to 3 times the pier length. Properties within 100 feet to 150 feet of a 50-foot pier could be subjected to wrack algae accumulation, sand deposition and shellfish population changes.” This evaluation cites no research results and appears to be based on predictive engineering calculations.

*Disruption during pile installation—*

Anecdotal evidence suggests that the method of piling installation can produce changes in sediment type and bottom morphology in the vicinity of a dock (Ziencina, 2002 pers. com.) Jetting of pilings (jetting uses a high pressure water pump to blow a deep hole in the bottom. The piling is set into the hole and sand packs back around the piling) tends to cause greater disruption than driving piles with a drop hammer. Jetting suspends sediments and can disrupt adjacent vegetation resulting in bare areas around pilings that are subject to scour. Shaefer (2001) found bare areas with a diameter of 35–78 inches around pilings in St. Andrew Bay, FL. Using a low pressure pump to produce a starter hole and subsequent insertion of a sharpened pile with a drop hammer in a sandy area “reduces the physical removal and disturbance” of seagrasses in the area of the piling and results in little to no sand deposition around the pilings (Shaefer, 2001)

*Pumping of sediments from floats or docks resting on or near the bottom—*

Observational evidence indicates that changes in sediments occur when floats or boats are allowed to settle on the bottom at low tide (Ziencina, 2002, pers. com.). As the floats rise they create a suction that resuspends sediments—the sediment is “pumped” into resuspension. Additionally wave refraction in a downward direction may also resuspend some sediments (Ludwig, 2003, pers. com.).

## Impacts from Boating Uses Associated with Small Docks—

Most small docks are associated with boat traffic. Being situated at the interface between land and water, at least a portion of each dock is in the intertidal zone and extends into or through shallow areas. In many cases this can lead to environmental impacts. Because docks are in the shallowest areas of an embayment and are the location where refueling may take place and engines are started and stopped, impacts are apt to be particularly significant. Propeller scarring of vegetation and “prop dredging” of sediments are perhaps the most visible impacts in the shallow waters adjacent to docks.

In 1994, a workshop on the impacts of boating was held at the Woods Hole Oceanographic Institution (Crawford *et al.*, 1998). A number of potential boating-related impacts were discussed although no differentiation was made between general boating activities and those taking place in the vicinity of docks. While noting that there were adverse impacts, the presentations revealed that there were limited quantitative data available that could be used as the basis for management decisions—although it was agreed that sufficient data exist to “substantiate the inference that recreational ... motor boat traffic is far from a benign influence on aquatic and marine environments.” A second symposium on the topic, “Impacts of Small Motorized Watercraft on Shallow Aquatic Systems” was held in 2000 at Rutgers University. The results of this symposium were published in Kennish (2002).

Both workshops identified several issues of concern regarding boating activity including:

- Impacts to submerged aquatic vegetation,
- Contamination from fuel discharges,
- Erosion on shorelines, and
- Resuspension of bottom sediments and turbidity.

### *Impacts on submerged vegetation—*

Boat propellers can directly damage submerged aquatic vegetation in shallow waters (Phillips, 1960; Thayer *et al.*, 1975; Zieman, 1976; Eleuterius, 1987; Kruer, 1998; Burdick and Short, 1999); impacts that may take years to heal. *Thalassia sp.*, for example, can take four to six years to recolonize a prop scar (Kruer, 1998). Damage to the plants and their rhizome system



**Figure 3.** Prop scarring in Waquoit Bay Massachusetts. From Crawford (2002)

often leads to both reduced wildlife habitat and destabilized sediments. Zieman (1976) reported that most propeller scarring takes place in water less than 1 meter (3.3 feet) in depth. Research in and around Corpus Christi Bay found that 39 percent of the seagrass meadows were either moderately (5–20 percent) or heavily (<20 percent) scarred based on the percentage of the area of the beds compared with the area of the propeller scars (Dunton and Schonberg, 2002).

#### *Contamination from fuel discharges—*

Outboard motors have long been associated with polluting of waterways. Milliken and Lee (1990) provide a good summary of the early literature. Two-cycle engines release up to 20 percent unburned fuel along with exhaust gases (Moore, 1998). Moore (1998) compared the polycyclic aromatic hydrocarbon (PAH), a carcinogenic organic molecule found in petroleum products, output from a two-cycle outboard engine with that from a four-cycle engine. The tests were run in tanks containing fresh water. The two-cycle motor discharged five times as much PAH as the four-cycle engine based on levels in the tanks. Most of this difference was due to a reduction in discharge of 2- and 3-ring compounds in the four-cycle. However, he found little difference between the levels of discharge of 4- and 5-ring compounds—those generally related to chronic toxicity. Albers (2002) notes that PAH concentrations in the water column are “usually several orders of magnitude below levels that are acutely toxic,” but those in sediments may be much higher.

Even when PAHs are found in coastal waters it is difficult to relate them directly to small dock use. Sanger and Holland (2002) looked at PAH levels in tidal creeks in South Carolina but were not able to distinguish PAHs from dock-related activities from other anthropogenic sources. Additionally, it is difficult to differentiate between general recreational boat use and that associated with small docks (Sanger, in Kelty and Bliven, 2003)

#### *Shoreline erosion—*

Boat wakes, which lap at the shoreline, can contribute to increased shore erosion (Zabawa *et al.* 1980; Camfield *et al.* 1980; Hagerty *et al.*, 1981). Most of these relate to boats moving at or near maximum speed through waterways. If boats are moving at a speed slow enough to avoid leaving a wake, there will not be shoreline erosion. There was little found in the literature that pertained specifically to boats maneuvering near docks or landing areas

#### *Resuspension of bottom sediments and turbidity—*

Running a motorized boat through shallow waters produces two distinct types of wake (Crawford, 1998):

- The primary wake (or bow wake) that is related to water displacement by the boat that moves out to the side and can cause bank erosion, and
- The secondary wake (or prop wash) related to engine and propeller effects that moves behind the boat and down and causes sediment resuspension and damage to submerged aquatic vegetation.

The secondary wake does not fan out as does the surface wake and consequently has localized impacts. Hartge (1998) compared prop-driven boats with those that were water-jet propelled and noted no major differences between the amount of resuspension of sediments; he did note that slow-moving, heavy laden boats caused more turbidity than lighter, faster moving boats.

Modern planning hulls (hulls designed to climb towards the surface of the water as power is applied, thus reducing the amount of wetted hull surface and reducing the friction or drag) also have a far lesser impact on bottom sediments (Crawford, 1998; Hartge, 1998). Secondary wake impacts are difficult to quantify accurately because they vary widely from boat to boat and based on environmental conditions. Propeller thrust characteristics are highly variable depending on:

- Propeller size,
- Thrust angle,
- Clearance over bottom,
- Engine power,
- Hull shape,
- Operating conditions (*e.g.*, speed, state of the tide, weather, number of passengers, and
- Operator choices. (Crawford in Kelty and Bliven, 2003).

Despite the ongoing research described above, there has been limited progress in finding quantifiable, predictable impacts from boating uses. This led Crawford (in Kelty and Bliven, 2003) to offer the following conclusions.

- Using sediment resuspension to assess impacts is not recommended because of the wide range of factors involved.
- Small-scale measurements of wave impacts are too variable; the broader the scale the better.
- It is difficult to ascribe generic impacts to an activity like boating that has such a wide range of variables.
- More research is needed—however the research is expensive and very time consuming.

## Bibliography for Environmental Impacts and Issues Module—

- Albers, P.H., 2002. Sources, fate, and effects of PAHs in shallow water environments: a review with special reference to small watercraft. *Journal of Coastal Research*. Special Issue 37.
- Alexander, C. R. and M.H. Robinson. 2004. *GIS and Field-Based Analysis of the Impacts of Recreational Docks on the Saltmarshes of Georgia*. Final Report prepared for the Georgia Coastal Zone Management Program. 40 pp.
- Anderson, Franz. 2000. *Effect of Wave-wash from Personal Watercraft on Salt Marshes*. A final report submitted to the NOAA/UNH Cooperative Institute for Coastal and Estuarine Environmental Technology (CICEET).
- Beal, J.L., B.S. Schmit, and S.L. Williams. 1999. *The effects of dock height and alternative construction materials on light irradiance (PAR) and seagrass Halodule wrightii and Syringodium filiforme cover*. Florida Department of Environmental Protection, Office of Coastal and Aquatic Managed Areas (CAMA). CAMA notes.
- Brooks, K.M. 1996. Evaluating the environmental risks associated with the use of chromated copper arsenate-treated wood products in aquatic environments. *Estuaries* 19:296–305.
- Burdick, D.M. and F.T. Short. 1998. *Dock Design with the Environment in Mind: Minimizing Dock Impacts to Eelgrass Habitats*. An interactive CD ROM published by the University of New Hampshire, Durham, NH.
- Burdick, D.M. and F.T. Short. 1999. The Effects of Boat Docks on Eelgrass Beds in Coastal Waters of Massachusetts. *Environmental Management*, 23: 231–240.
- Burns, Max. 1999. *The Dock Manual*. Storey Books, Schoolhouse Road, Pownal, Vermont 05261. (800) 793-9396. 201 pp.
- Camfield, F. E., R.E.L. Ray, and J.W. Eckert. 1980. *The Possible Impact of Vessel Wakes on Bank Erosion*. Prepared by USACOE, Fort Belvoir, Virginia, for US Department of Transportation and US Coast Guard, Washington, D.C. Report No. USCG-W-1-80 114 pp. NTIS No. ADA-083-896.
- Colligan, Mary and Cori Collins. 1995. *The Effect of Open-Pile Structures on Salt Marsh Vegetation*. NOAA/NMFS Habitat and Protected Resources Division. Pre-publication copy—not for distribution. 44p.
- Cooper, P.A. 1990. Leaching of CCA from Treated Wood. *Proc. Canadian Wood Preservation Association* II: 144–169.
- Crawford, R. N.Stolpe and M. Moore, Eds. 1998. *The Environmental Impacts of Boating: Proceedings of a workshop held at Woods Hole Oceanographic Institution, Woods Hole, MA. December 7–9 1994*. Technical Report WHOI-98-03
- Crawford, R. 1998. Measuring Boating Effects of Turbidity in a Shallow Coastal Lagoon. In *The Environmental Impacts of Boating: Proceedings of a workshop held at Woods Hole*

*Oceanographic Institution, Woods Hole, MA December 7–9 1994. Technical Report: WHOI-98-03. R. Crawford, N. Stolpe and M. Moore. Eds.*

Crawford, R. 2002. Secondary Wake Turbidity From Small Boat Operation in a Shallow, Sandy Bay. *Journal of Coastal Research* Special Issue 37.

Dunton, Kenneth H. and Susan Schonberg. 2002. Assessment of Propeller Scarring in Seagrass Beds of the South Texas Coast. *Journal of Coastal Research*. Special Issue 37.

Eluterius, L.N. 1987. Seagrass ecology along the coasts of Alabama, Louisiana, and Mississippi. In Durako, M.J., R.C. Phillips, and R.R. Lewis III (Eds.). *Proceedings of the Symposium of Subtropical-tropical Seagrasses of the Southeastern United States*. Florida Marine Research Publications No. 42 pp. 11–24.

Evert, C.H., and A.E. DeWall. 1975. *Coastal Sand Level Changes in North Carolina*. Draft Report, Coastal Engineering Research Center, US Army Corps of Engineers.

Garrison, Paul J., David W. Marshall, Laura Stremick-Thompson, Patricia L. Cicero, and Paul D. Dearlove. 2005. *Effects of pier shading on littoral zone habitat and communities in Lakes Ripley and Rock, Jefferson County, Wisconsin*. Wisconsin Department of Natural Resources, Jefferson County Land and Water Conservation Department and Lake Ripley Management District. Pub-SS-1006 2005.

Hagerty, D. J., M.F. Spoor and C.R. Ullrich. 1981. Bank Failure and Erosion on the Ohio River. *Engineering Geology*. 17:141–158.

Hartge, P. 1998. Boating Induced Turbidity. In *The Environmental Impacts of Boating: Proceedings of a workshop held at Woods Hole Oceanographic Institution, Woods Hole, MA December 7–9 1994*. Technical Report WHOI-98-03. R. Crawford, N. Stolpe and M. Moore. Eds.

Hruby, T. 1990. *Long Island region tidal wetlands management manual. Part III: Management Plan Development*. Seatuck Research Program, Islip, NY 42 pp.

Johnson, J.W. 1973. Proposal preparation for Department of Navigation and Ocean Development. Unpublished information.

Kearney, V., Y. Segal and M.W. Lefor. 1983. *The Effects of Docks on Salt Marsh Vegetation*. The Connecticut State Department of Environmental Protection, Water Resources Unit, Hartford, CT. 06106.

Kelty, Ruth and Steve Bliven. 2003. *Environmental and Aesthetic Impacts of Small Docks and Piers: Workshop Report: Developing a Science-Based Decision Support Tool for Small Dock Management, Phase 1: Status of the Science*. NOAA Coastal Ocean Program, Decision Analysis Series Number 22. NOAA Coastal Ocean Program, 1305 East-West Highway, Silver Spring, MD, 20910. Copies of the report may be downloaded from [www.nccos.noaa.gov/publications/notables.html#dp\\_](http://www.nccos.noaa.gov/publications/notables.html#dp_).

Kennish, Michael J., (Editor). 2002. Impacts of Motorized Watercraft on Shallow Estuarine and Coastal Marine Environments. *Journal of Coastal Research*. Special Issue 37.

- Kenworthy, Judson W. and Daniel E. Haurert (eds.) 1991. *The Light Requirements of Seagrasses; proceedings of a workshop to examine the capability of water quality criteria, standards and monitoring programs to protect seagrasses*. NOAA Technical Memorandum NMFS-SEFC-287. NMFS Beaufort Laboratory, Beaufort, NC 28516-9722.
- Koch, E.W. and S. Beer. 1996. Tides, light and the Distribution of *Zostera marina* in Long Island Sound, USA. *Aquatic Biology*. 53: 97–107.
- Kruer, Curtis. 1998. Boating Impacts On Seagrass Habitats In Florida. In *The Environmental Impacts of Boating: Proceedings of a workshop held at Woods Hole Oceanographic Institution, Woods Hole, MA December 7–9 1994*. Technical Report: WHOI-98-03. R. Crawford, N. Stolpe and M. Moore. Eds.
- Lefor, Michael Wm. 1992. In *Restoring Connecticut's Coastal Resources: A handbook for municipal officials*. Connecticut Sea Grant Publications #CT-SG-92-04.
- Ludwig, Michael. 2003. National Marine Fisheries Service, Milford (CT) Laboratory.
- Luoma, S. N., and J. A. Davis. 1983. Requirements for modeling trace metal partitioning in oxidized estuarine sediments. *Marine Chemistry* 12:159-181.
- Luoma, S.N. and Carter, J.L. 1991. Effects of trace metals on aquatic benthos. In *Metal Ecotoxicology: Concepts and Applications*. Newman, M.C. and McIntosh, A.W., Eds Chelsea, MI., Lewis Publishers, p. 261–300.
- Maine State Planning Office, Maine Coastal Program. 1997. *The Waterfront Construction Handbook: Guidelines for the Design and Construction of Waterfront Facilities*. Maine Coastal Program, 38 State House Station, Augusta, ME. 04330. 93 pp.
- McGuire, H.L. 1990. *The Effects of Shading by Open-pile Structures on the Density of Spartina alterniflora*. Unpublished Master's Thesis from the Virginia Institute of Marine Science.
- Milliken, A. S., and V. Lee. 1990. *Pollution impacts from recreational boating: A bibliography and summary review*. Rhode Island Sea Grant. P 1134. RIU-G-90-002. 26 pp.
- Miller, H.C., W.A. Birekmeir, and A.E. DeWall. 1983. *Effects of CERC Research Pier on Nearshore Processes*. US Army Coastal Engineering Research Center. Reprint 83-13.
- Moore, Michael. 1998. Aromatic Hydrocarbons: Two-Cycle vs. Four-cycle. In *The Environmental Impacts of Boating: Proceedings of a workshop held at Woods Hole Oceanographic Institution, Woods Hole, MA December 7–9 1994*. Technical Report WHOI-98-03. R. Crawford, N. Stolpe and M. Moore. Eds.
- Nightengale, B and C. Simenstad. 2001. *White paper—overwater structures: marine issues*. Rept. No. WA-RD 508.1, Washington State Transportation Center, University of Washington, Seattle, WA. 133 pp + append.

- Noble, Ronald. 1978. Coastal Structures' Effects on Shorelines. In *Proceedings of the Sixteenth Coastal Engineering Conference*, v. III. American Society of Civil Engineers. New York, NY.
- Phillips, R.C. 1960. *Observations of the Ecology and Distribution of Florida Seagrasses*. Professional Paper Series 2. State Board of Conservation Marine Laboratory. St. Petersburg, FL
- Poole, Bruce M. 1987. *Diagnostic/Feasibility Study for Lagoon Pond Oak Bluffs, Tisbury, MA*. SP Engineering, Inc. Salem MA
- Sanger, D.M., A.F. Holland and G.I. Scott. 1999. Tidal creek and salt marsh sediments in South Carolina Coastal Estuaries. I. Distribution of trace metals. *Archives of Environmental Contamination and Toxicology* 37:936–943.
- Sanger, D.M. and A.F. Holland. 2002. *Evaluation of the Impacts of Dock Structures on South Carolina Estuarine Environments*. SC Department of Natural Resources, Marine Resources Division Technical Report Number 99. Charleston, SC.
- Shaefer, D. 1999. The Effects of Dock Shading on the Seagrass *Halodule wrightii* in Perdido Bay, Alabama. *Estuaries* 22: 936–943.
- Shaefer, D. and J. Lundin. 1999. *Design and Construction of Docks to Minimize Seagrass Impacts*. US Army Corps of Engineers WRP Technical Note VN–RS–3.1 June 1999. Available at [www.wes.army.mil/el/wrtc/wrp/tnotes/vnrs3-1.pdf](http://www.wes.army.mil/el/wrtc/wrp/tnotes/vnrs3-1.pdf)
- Shaefer, D and J. Robinson. 2001. An evaluation of the use of grid platforms to minimize shading impacts to seagrasses. *WRAP Technical Notes Collection* (ERDC TN-WRAP–01–02. US Army Engineer Research and Development Center, Vicksburg, MS. Available at [www.wes.army.mil/el/wrap](http://www.wes.army.mil/el/wrap).
- Smith, K. and R. Mezich. 1999. *Comprehensive assessment of the effects of single family docks on seagrass in Palm Beach County, Florida*. Draft Report for the Florida Fish and Wildlife Conservation Commission, Tallahassee, FL.
- Southern Pine Council. 2004. *Pressure-Treated Southern Pine: standards, specifications, applications*. Available through the Southern Forest Products Association, P.O. Box 641700 Kenner, LA 70064-1700 (504) 443-4464 or Southeastern Lumber Manufacturers Association, P.O. Box 1788, Forest Park, GA. (404) 361-1445.
- Thayer, G.W., D.A. Wolff and R. B. Williams. 1975. The Impact of Man on Seagrass. *American Scientist* 63:288–296.
- Teal, John. 1962. Energy Flow in the Salt Marsh Ecosystem. *Ecology* 43: 614–624.
- Teal, John, and Mildred Teal. 1969. *Life and Death of a Saltmarsh*. Little, Brown and Company.
- Teal, John. 1986. *The Ecology of Regularly Flooded Salt Marshes of New England: A Community Profile*. U.S. Fish and Wildlife Service. Biological Report 85(7.4).

- Vernberg, F.J. 1996. Ecology of Southeastern Saltmarshes. In *Sustainable Development in the Southeastern Coastal Zone*. Eds. Vernberg, F.J., W.B. Venberg and T. Siewicki. University of South Carolina Press.
- Weigert, R.G., L.R. Pomeroy, and W.J. Wiebe. 1981. Ecology of Salt Marshes: An Introduction. In *The Ecology of a Saltmarsh*. Eds. L.R. Pomeroy and R.G. Wiegert. Springer-Verlag.
- Weinstein, J.E. 1996. Anthropogenic Impacts on Salt Marshes—A Review. In *Sustainable Development in the Southeastern Coastal Zone*. Eds. Vernberg, F.J., W.B. Venberg and T. Siewicki. University of South Carolina Press.
- Weis, P., J.S. Weis, and L.M. Coohill. 1991. Toxicity to Estuarine Organisms of Leachates from Chromated Copper Arsenate Treated Wood. *Archives of Environmental Contamination and Toxicology*. 20: 118–124.
- Weis, P., J.S. Weis, A. Greenberg, and T.J. Nosker. 1992. Toxicity of Construction Materials in the Marine Environment: A Comparison of Chromated-Copper-arsenate-Treated Wood and Recycled Plastic. *Archives of Environmental Contamination and Toxicology*. 22: 99–106.
- Weis, P. J.S. Weis and J. Couch 1993. Histopathology and bioaccumulation in oysters (*Crassostrea virginica*) living on wood preserved with chromated copper arsenate. *Diseases of Aquatic Organisms*. 17: 41-46.
- Weis, J.S., P. Weis, and T. Proctor. 1998. The extent of benthic impacts of CCA-treated wood structures in Atlantic Coast Estuaries. *Archives of Environmental Contamination and Toxicology*. 34: 313–322.
- Weis, J.S. and P. Weis. 1996. The effects of using wood treated with chromated copper arsenate in shallow water environments: a review. *Estuaries* 19:306–310.
- Weis, J.S. and P. Weis. 1998. *Effects of CCA Wood Docks and Resulting Boats on Bioaccumulation of Contaminants in Shellfish Resources: Final Report to DEP*. A report to the NJ DEP.
- Wendt, P.H., R.F. Van Dolah, M.Y. Bobo, T.D. Mathews, and M.V. Levisen. 1996. Wood Preservative Leachates from Docks in an Estuarine Environment. *Archives of Environmental Contamination and Toxicology*, 31:71–79.
- Wilson, Joshua. 2002. *The Effects of Docks and Mechanical Disturbance on Submerged Aquatic Vegetation in Tidal-Fresh Hamburg Cove (Lyme, CT)*. Yale School of Forestry and Environmental Studies.
- Zabawa, C., C. Ostrom, R. J. Byrne, J. D. Boon III, R. Waller, and D. Blades. 1980. *Final report on the role of boat wakes in shore erosion in Anne Arundel County, Maryland*. Tidewater Administration, Maryland Dept. of Natural Resources. 12/1/80. 238 pp
- Zieman, J.C. 1976. The ecological effects of physical damage from motorboats on turtle grass beds in southern Florida. *Aquatic Botany* 2:127–139

Ziencina, Mitchell. 2002. Massachusetts Department of Environmental Protection, Lakeville, MA.